CLAIMS

What is claimed is:

1. A thermoacoustic device comprising:

a thermoacoustic engine for moving a fluid using acoustic power, said thermoacoustic engine comprising a wall forming a chamber, said wall having one or more orifices formed therein;

wherein said one or more orifices and said wall are sized and configured such that movement of said fluid by said thermoacoustic engine forms a synthetic jet at said one or more orifices.

2. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a stack.

3. The thermoacoustic device of claim 2, wherein said thermoacoustic engine comprises a first end, a second end and a center between said first end and said second end, and wherein said stack is positioned in said chamber between said first end and said center.

4. The thermoacoustic device of claim 2, wherein said stack comprises a series of spaced apart plates.

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5. The thermoacoustic device of claim 4, wherein said spaced apart plates are aligned substantially parallel to a longitudinal axis of the chamber.

6. The thermoacoustic device of claim 2, wherein said stack comprises a spiral member.

7. The thermoacoustic device of claim 2, wherein said stack comprises a plurality of rods.

8. The thermoacoustic device of claim 2, wherein said stack comprises a plurality of tubes.

9. The thermoacoustic device of claim 2, wherein said stack comprises a polygonal grid.

10. The thermoacoustic device of claim 2, wherein said stack comprises a triangular grid.

11. The thermoacoustic device of claim 2, wherein said stack comprises a square grid.

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12. The thermoacoustic device of claim 2, wherein said stack comprises a hexagonal grid.

13. The thermoacoustic device of claim 2, wherein said stack comprises a tortuous path between a hot end of said stack and a cold end of said stack.

14. The thermoacoustic device of claim 2, wherein said stack comprises a plurality of channels in silicon.

15. The thermoacoustic device of claim 2, wherein said thermoacoustic engine is configured such that said fluid is allowed to contact said stack at approximate ambient temperatures to form a cold end of said stack.

16. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a first end and a second end, and wherein said first end of said thermoacoustic engine is configured to be joined with an object to be cooled.

17. The thermoacoustic device of claim 1, wherein said thermoacoustic engine has a length and a width, wherein said length is longer than said width.

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18. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a first heat exchanger.

19. The thermoacoustic device of claim 18, wherein said first heat exchanger is formed of a heat conducting material.

20. The thermoacoustic device of claim 18, wherein said first heat exchanger comprises holes inside the thermoacoustic engine to allow said fluid to flow therethrough.

21. The thermoacoustic device of claim 15, wherein said thermoacoustic engine comprises a first heat exchanger located on a hot end of said stack positioned opposite said cold end of said stack.

22. The thermoacoustic device of claim 21, wherein said first heat exchanger is formed as a screen.

23. The thermoacoustic device of claim 1, wherein the thermoacoustic engine is configured to be disposed directly on an object to be cooled without an intervening heat exchanger.

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24. The thermoacoustic device of claim 1, wherein said one or more orifices comprise a plurality of orifices.

25. The thermoacoustic device of claim 24, wherein said thermoacoustic engine comprises a longitudinal axis and said plurality of orifices are formed in said wall in an orientation transverse to said longitudinal axis.

26. The thermoacoustic device of claim 1, wherein said thermoacoustic engine has a stroke length, and said one or more orifices each have a diameter, and wherein a ratio of said stroke length over said diameter is greater than 1.

27. The thermoacoustic device of claim 1, wherein said thermoacoustic engine has a stroke length, and said one or more orifices each have a cross stream width, wherein a ratio of said stroke length over said cross stream width is between approximately 1 and approximately 10.

28. The thermoacoustic device of claim 1, wherein said thermoacoustic engine has a stroke length, and said one or more orifices each have a cross stream width, wherein a ratio

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of said stroke length over said cross stream width is between approximately 3 and approximately 8.

29. The thermoacoustic device of claim 1, wherein said thermoacoustic engine has a stroke length, and said one or more orifices each have a cross stream width, wherein a ratio of said stroke length over said cross stream width is between approximately 5.5 and approximately 6.0.

30. The thermoacoustic device of claim 16, wherein said one or more orifices are located in said second end of said thermoacoustic engine.

31. The thermoacoustic device of claim 2, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

32. The thermoacoustic device of claim 1, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

33. A thermoacoustic engine for cooling an object, said thermoacoustic engine comprising:

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a resonator configured and dimensioned for generating acoustic power, said resonator having a wall defining a chamber;

a stack positioned within said chamber, said stack having a hot end and a cold end; and

a first heat exchanger disposed on said hot end of said stack;

wherein said cold end of said stack contacts a fluid within said chamber without an intervening second heat exchanger such that heat is transferred from said stack to said fluid.

34. The thermoacoustic engine of claim 33, further comprising one or more orifices in said wall for forming a synthetic jet such that said fluid is allowed to pass from said chamber to a position outside of said chamber.

35. The thermoacoustic engine of claim 33, wherein said thermoacoustic engine comprises a first end and a second end, and wherein said first end of said thermoacoustic engine is configured to be joined with an object to be cooled.

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36. The thermoacoustic engine of claim 33, wherein said first heat exchanger comprises holes inside the thermoacoustic engine to allow said fluid to flow therethrough.

37. The thermoacoustic engine of claim 34, wherein said one or more orifices comprise a plurality of orifices.

38. The thermoacoustic engine of claim 37, wherein said thermoacoustic engine comprises a longitudinal axis and said plurality of orifices are formed in said wall in an orientation transverse to said longitudinal axis.

39. The thermoacoustic engine of claim 35, wherein said one or more orifices are located in said second end of said thermoacoustic engine.

40. The thermoacoustic engine of claim 33, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

41. The thermoacoustic engine of claim 33, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

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42. A thermoacoustic cooling system comprising:

a thermoacoustic engine, said thermoacoustic engine comprising means for forming a synthetic jet for transporting a flow of fluid out of said thermoacoustic engine; and

an object to be cooled;

wherein said thermoacoustic engine is disposed on said object to be cooled such that heat produced by said object is carried through said thermoacoustic engine and away from said object by said synthetic jet.

43. The thermoacoustic cooling system of claim 42, wherein said thermoacoustic engine comprises a wall forming a chamber.

44. The thermoacoustic cooling system of claim 43, wherein said means for forming a synthetic jet comprises one or more orifices in said wall.

45. The thermoacoustic cooling system of claim 44, wherein said thermoacoustic engine comprises a longitudinal axis and said one or more orifices are formed in said wall in an orientation transverse to said longitudinal axis.

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46. The thermoacoustic cooling system of claim 44, wherein said one or more orifices are located in an end of said thermoacoustic engine.

47. The thermoacoustic cooling system of claim 42, wherein said object to be cooled comprises a chip.

48. The thermoacoustic cooling system of claim 42, wherein thermoacoustic engine further comprises a stack.

49. The thermoacoustic cooling system of claim 48, wherein said stack has a hot end and a cold end and a first heat exchanger disposed on said hot end.

50. The thermoacoustic cooling system of claim 48, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

51. The thermoacoustic cooling system of claim 43, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

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52. A thermoacoustic cooling system comprising:

a thermoacoustic engine, said thermoacoustic engine comprising a resonator having a wall defining a chamber, said thermoacoustic engine being disposed on a chip;

wherein one or more orifices are formed in said wall of said resonator for providing a passageway for fluid to pass from said chamber to a position outside of said chamber.

53. The thermoacoustic cooling system of claim 52, further comprising cooling means for cooling said thermoacoustic engine.

54. The thermoacoustic cooling system of claim 53, wherein said cooling means comprises a fan for moving said fluid outside said resonator.

55. The thermoacoustic cooling system of claim 52, further comprising external heating means for heating said thermoacoustic engine.

56. The thermoacoustic cooling system of claim 52, further comprising cooling means for cooling said

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thermoacoustic engine, and external heating means for heating said thermoacoustic engine.

57. The thermoacoustic cooling system of claim 52, wherein thermoacoustic engine further comprises a stack.

58. The thermoacoustic cooling system of claim 57, wherein said stack has a hot end and a cold end and a first heat exchanger disposed on said hot end.

59. The thermoacoustic cooling system of claim 48, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

60. The thermoacoustic cooling system of claim 52, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid.

61. The thermoacoustic cooling system of claim 52, wherein said one or more orifices are configured for forming a synthetic jet.

62. A thermoacoustic cooling system comprising:

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a thermoacoustic engine, said thermoacoustic engine comprising a resonator defining a chamber, said thermoacoustic engine being disposed on a chip; and

a first heat exchanger disposed on said chip;

wherein heat from said chip is carried through said first heat exchanger to power said thermoacoustic engine and cool said chip.

63. The thermoacoustic cooling system of claim 62, wherein said thermoacoustic engine comprises a wall and one or more orifices are formed in said wall for forming a synthetic jet.

64. The thermoacoustic cooling system of claim 62, further comprising cooling means for cooling said thermoacoustic engine.

65. The thermoacoustic cooling system of claim 64, wherein said cooling means comprises a fan for moving said fluid outside said resonator.

66. The thermoacoustic cooling system of claim 62, wherein thermoacoustic engine further comprises a stack.

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67. The thermoacoustic cooling system of claim 66, wherein said stack has a hot end and a cold end and said first heat exchanger is disposed on said hot end.

68. The thermoacoustic cooling system of claim 66, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

69. The thermoacoustic cooling system of claim 63, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

70. A thermoacoustic cooling system comprising:

a thermoacoustic engine, said thermoacoustic engine comprising means for forming a synthetic jet for transporting a flow of fluid out of said thermoacoustic engine; and

a fan for moving said fluid away from said thermoacoustic engine.

71. The thermoacoustic cooling system of claim 70, wherein said thermoacoustic engine comprises a wall forming a chamber.

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72. The thermoacoustic cooling system of claim 71, wherein said means for forming a synthetic jet comprises one or more orifices in said wall.

73. The thermoacoustic cooling system of claim 70, wherein thermoacoustic engine further comprises a stack.

74. The thermoacoustic cooling system of claim 73, wherein said stack has a hot end and a cold end and a first heat exchanger is disposed on said hot end.

75. The thermoacoustic cooling system of claim 73, wherein said stack comprises a barrier to prevent said fluid from passing through said stack at said barrier.

76. The thermoacoustic cooling system of claim 71, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

77. The thermoacoustic cooling system of claim 70, wherein said thermoacoustic engine is disposed on a chip.

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78. A method for cooling an object, said method comprising the steps of:

(a) joining a thermoacoustic engine to said object;

(b) using heat in said object to power said thermoacoustic engine; and

(c) using said thermoacoustic engine to form a synthetic jet to move said heat away from said object.

79. The method of claim 78, wherein step (a) comprises joining said thermoacoustic engine to a chip.

80. The method of claim 78, wherein step (a) comprises placing a first heat exchanger on said object.

81. The method of claim 78, further comprising moving fluid in said thermoacoustic engine using acoustic power.

82. The method of claim 78, wherein said thermoacoustic engine comprises a stack having a hot end and a cold end, wherein the method further comprises the step of heating said hot end of said stack with said object.

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83. The method of claim 82, further comprising cooling said cold end of said stack with ambient air.

84. The method of claim 82, further comprising cooling said cold end of said stack with a stack cooling means.

85. The method of claim 82, further comprising providing a first heat exchanger on said hot end of said stack.

86. The method of claim 78, further comprising circulating ambient air through said thermoacoustic engine with said synthetic jet.

87. The method of claim 78, further comprising operating said thermoacoustic engine at a frequency beyond a range detectable by human hearing.

88. The method of claim 78, further comprising forming a plurality of synthetic jets.

89. The method of claim 78, wherein said thermoacoustic engine comprises a longitudinal axis and wherein step (c)

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further comprises directing said synthetic jet in a direction transverse to said longitudinal axis.

90. The method of claim 78, wherein said thermoacoustic engine comprises a longitudinal axis and wherein step (c) further comprises directing said synthetic jet in a direction substantially parallel to said longitudinal axis.

91. The method of claim 82, further comprising forming a barrier on said stack.

92. The method of claim 78, further comprising directing a flow of fluid in said thermoacoustic engine.

93. The method of claim 78, further comprising reducing a volume of a portion of said thermoacoustic engine.

94. A method for cooling an object, said method comprising the steps of:

(a) joining a thermoacoustic engine to said object;

(b) using heat produced by said object to power said thermoacoustic engine; and

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Fax: (801) 255-5338

(c) transferring said heat through said thermoacoustic engine to move said heat away from said object.

95. The method of claim 94, further comprising forming a synthetic jet to transfer said heat through said thermoacoustic engine.

96. The method of claim 94, wherein step (a) comprises joining said thermoacoustic engine to a chip.

97. The method of claim 94, wherein step (a) comprises placing a first heat exchanger on said object.

98. The method of claim 94, further comprising moving fluid in said thermoacoustic engine using acoustic power.

99. The method of claim 94, wherein said thermoacoustic engine comprises a stack having a hot end and a cold end, wherein the method further comprises the step of heating said hot end of said stack with said object.

100. The method of claim 99, further comprising cooling said cold end of said stack with ambient air.

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101. The method of claim 99, further comprising cooling said cold end of said stack with a stack cooling means.

102. The method of claim 99, further comprising providing a first heat exchanger on said hot end of said stack.

103. The method of claim 95, further comprising circulating ambient air through said thermoacoustic engine with said synthetic jet.

104. The method of claim 94, further comprising operating said thermoacoustic engine at a frequency beyond a range detectable by human hearing.

105. The method of claim 94, further comprising forming a plurality of synthetic jets to transfer said heat through said thermoacoustic engine.

106. The method of claim 95, wherein said thermoacoustic engine comprises a longitudinal axis and the method further comprises directing said synthetic jet in a direction transverse to said longitudinal axis.

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107. The method of claim 95, wherein said thermoacoustic engine comprises a longitudinal axis and the method further comprises directing said synthetic jet in a direction substantially parallel to said longitudinal axis.

108. The method of claim 99, further comprising forming a barrier on said stack.

109. The method of claim 94, further comprising directing a flow of fluid in said thermoacoustic engine.

110. The method of claim 94, further comprising reducing a volume of a portion of said thermoacoustic engine.

111. A thermoacoustic device comprising:

a thermoacoustic engine comprising a wall forming a chamber, and a stack positioned in said chamber;

wherein said wall comprises one or more orifices and said stack comprises a barrier such that when a fluid flowing from said one or more orifices contacts said barrier, said fluid is directed to circulate in said chamber without passing through said stack.

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112. The thermoacoustic device of claim 111, wherein each of said one or more orifices is configured for forming a synthetic jet for moving said fluid in and out of said chamber.

113. The thermoacoustic device of claim 111, wherein said stack comprises a series of spaced apart plates.

114. The thermoacoustic device of claim 111, wherein said stack comprises a spiral member.

115. The thermoacoustic device of claim 111, wherein said stack comprises a plurality of rods.

116. The thermoacoustic device of claim 111, wherein said stack comprises a plurality of tubes.

117. The thermoacoustic device of claim 111, wherein said stack comprises a polygonal grid.

118. The thermoacoustic device of claim 111, wherein said stack comprises a triangular grid.

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119. The thermoacoustic device of claim 111, wherein said stack comprises a square grid.

120. The thermoacoustic device of claim 111, wherein said stack comprises a hexagonal grid.

121. The thermoacoustic device of claim 111, wherein said stack comprises a tortuous path between a hot end of said stack and a cold end of said stack.

122. The thermoacoustic device of claim 111, wherein said stack has a cold end and a hot end, and wherein said barrier prevents movement of said fluid from said cold end of said stack to said hot end of said stack at said barrier.

123. The thermoacoustic device of claim 111, wherein said thermoacoustic engine comprises a first end and a second end, and wherein said first end of said thermoacoustic engine is configured to be joined with an object to be cooled.

124. The thermoacoustic device of claim 111, wherein said thermoacoustic engine comprises a first heat exchanger.

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125. The thermoacoustic device of claim 111, wherein said thermoacoustic engine comprises a longitudinal axis and said one or more orifices are formed in said wall in an orientation substantially parallel to said longitudinal axis.

126. The thermoacoustic device of claim 111, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid in said chamber.

127. A thermoacoustic device comprising:

a thermoacoustic engine comprising a wall forming a chamber, said wall comprising one or more orifices; and

a barrier in said chamber, said barrier being aligned with said one or more orifices such that when a fluid flowing from said one or more orifices contacts said barrier, said fluid is directed to circulate in said chamber.

128. The thermoacoustic device of claim 127, further comprising a stack in said chamber.

129. The thermoacoustic device of claim 128, wherein said barrier is formed on said stack.

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130. The thermoacoustic device of claim 127, wherein said barrier is formed as a solid member characterized by an absence of through passages.

131. The thermoacoustic device of claim 127, wherein each of said one or more orifices is configured for forming a synthetic jet for moving said fluid in and out of said chamber.

132. The thermoacoustic device of claim 128, wherein said stack has a cold end and a hot end, and wherein said barrier prevents movement of said fluid from said cold end of said stack to said hot end of said stack at said barrier.

133. The thermoacoustic device of claim 127, wherein said thermoacoustic engine comprises a first end and a second end, wherein said first end of said thermoacoustic engine is configured to be joined with an object to be cooled and said one or more orifices are located in said second end.

134. The thermoacoustic device of claim 127, wherein said thermoacoustic engine comprises a first heat exchanger.

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135. The thermoacoustic device of claim 127, wherein said thermoacoustic engine comprises a longitudinal axis and said one or more orifices are formed in said wall in an orientation substantially parallel to said longitudinal axis.

136. The thermoacoustic device of claim 127, wherein said wall comprises a taper for reducing a volume of said chamber and directing movement of said fluid.

137. A thermoacoustic device comprising:

a thermoacoustic engine comprising a wall forming a chamber, said chamber having an interior surface and one or more orifices in said wall;

wherein said interior surface tapers toward said one or more orifices to direct a flow of fluid toward said one or more orifices.

138. The thermoacoustic device of claim 137, further comprising a barrier in said chamber, said barrier being aligned with said one or more orifices.

139. The thermoacoustic device of claim 137, further comprising a stack in said chamber.

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140. The thermoacoustic device of claim 137, wherein each of said one or more orifices is configured for forming a synthetic jet for moving said fluid in and out of said chamber.

141. The thermoacoustic device of claim 137, wherein said thermoacoustic engine comprises a first end and a second end, wherein said first end of said thermoacoustic engine is configured to be joined with an object to be cooled and said one or more orifices are located in said second end.

142. The thermoacoustic device of claim 137, wherein said thermoacoustic engine comprises a first heat exchanger.

143. A method for forming a stack, said method comprising the steps of:

(a) joining a stack material and a sacrificial material;

(b) rolling the stack material and the sacrificial material together; and

(c) removing the sacrificial material such that the stack material remains.

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144. The method of claim 142, wherein the step of joining a stack material and a sacrificial material comprises joining stainless steel and lead.

145. The method of claim 142, further comprising brazing a brace on said stack material to hold said stack material in place.

146. The method of claim 145, wherein the step of brazing a brace further comprises forming a multi-arm brace and connecting arms of said multi-arm brace to edges of the stack material.

147. The method of claim 146, wherein the arms of the multi-arm brace extend in a radial direction with respect to the stack material in a rolled configuration.

148. The method of claim 142, further comprising sintering metal on said stack material to hold said stack material in place.

149. The method of claim 148, wherein the step of sintering metal on said stack material further comprises

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forming a multi-arm brace and connecting arms of said multi-arm brace to edges of the stack material.

150. The method of claim 142, wherein step (c) comprises heating said sacrificial material to melt said sacrificial material away from said stack material.

151. The method of claim 142, wherein step (c) comprises chemically washing said sacrificial material away from said stack material.

152. The method of claim 142, further comprising holding said stack material together.

153. The method of claim 152, wherein holding said stack material together comprises placing said stack material in a sleeve.

154. The method of claim 152, wherein holding said stack material together comprises welding said stack material.

155. A thermoacoustic system comprising:

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a thermoacoustic engine for moving a fluid using acoustic power, said thermoacoustic engine comprising a wall forming a chamber, said wall having one or more orifices formed therein;

wherein said one or more orifices and said wall are sized and configured such that movement of said fluid by said thermoacoustic engine forms a synthetic jet at said one or more orifices;

wherein said thermoacoustic engine comprises a stack;

wherein said stack comprises a spiral member;

wherein said thermoacoustic engine comprises a first end, a second end and a center between said first end and said second end, and wherein said stack is positioned in said chamber between said first end and said center;

wherein said thermoacoustic engine is configured such that said fluid is allowed to contact said stack at approximate ambient temperatures to form a cold end of said stack;

wherein said thermoacoustic engine comprises a first heat exchanger located on a hot end of said stack positioned opposite said cold end of said stack;

wherein said first heat exchanger is formed of a heat conducting material;

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wherein said first heat exchanger comprises holes inside the thermoacoustic engine to allow said fluid to flow therethrough;

wherein said thermoacoustic engine has a length and a width, wherein said length is longer than said width;

wherein said one or more orifices comprise a plurality of orifices;

wherein said thermoacoustic engine comprises a longitudinal axis and said plurality of orifices are formed in said wall in an orientation transverse to said longitudinal axis;

wherein said thermoacoustic engine has a stroke length, and said plurality of orifices each have a cross stream width, wherein a ratio of said stroke length over said cross stream width is between approximately 5.5 and approximately 6.0;

wherein the first end of the thermoacoustic engine is joined with an object to be cooled;

wherein the object to be cooled is a chip.

156. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a first end and a second end, wherein said chamber is enclosed at said first end and said second end said wall.

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157. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a first end and a second end, wherein said chamber is enclosed by said wall at one of said first end and said second end.

158. The thermoacoustic device of claim 1, wherein said thermoacoustic engine comprises a first end and a second end, wherein said wall defines an opening at each of said first end and said second end.

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